US009184424B2

(12) **United States Patent**
Arena et al.

(10) **Patent No.: US 9,184,424 B2**
(45) **Date of Patent: Nov. 10, 2015**

(54) **BATTERY ASSEMBLY**

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(73) Assignee: **LG Chem, Ltd.**, Seoul (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 241 days.

(21) Appl. No.: **13/936,556**

(22) Filed: **Jul. 8, 2013**

(65) **Prior Publication Data**

US 2015/0010801 A1 Jan. 8, 2015

(51) **Int. Cl.**

H01M 2/10	(2006.01)
H01M 10/647	(2014.01)
H01M 10/6557	(2014.01)
H01M 10/6555	(2014.01)
H01M 10/6561	(2014.01)
H01M 10/613	(2014.01)
H01M 10/04	(2006.01)
H01M 2/20	(2006.01)

(52) **U.S. Cl.**

CPC ***H01M 2/10*** (2013.01); ***H01M 10/613*** (2015.04); ***H01M 10/647*** (2015.04); ***H01M 10/6555*** (2015.04); ***H01M 10/6557*** (2015.04); ***H01M 10/6561*** (2015.04); *H01M 2/202* (2013.01); *H01M 10/0486* (2013.01)

(58) **Field of Classification Search**

CPC H01M 10/0486

See application file for complete search history.

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Primary Examiner — Jane Rhee

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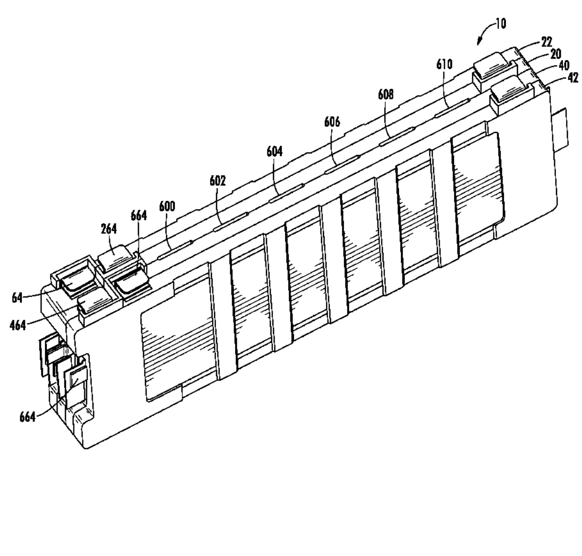
(57) **ABSTRACT**

A battery assembly includes a first battery frame assembly having a first plastic frame member and a first thermally conductive plate. The first plastic frame member has a rectangular ring-shaped peripheral wall and a plurality of cross-members. The battery assembly further includes a first thermally conductive plate having peripheral edges encapsulated within the first substantially rectangular ring-shaped peripheral wall. The plate further includes exposed portions configured to contact air passing through a first plurality of channels in the peripheral wall and past the first thermally conductive plate and through a second plurality of channels in the peripheral wall. The battery assembly further includes a first battery cell configured to contact the first thermally conductive plate.

14 Claims, 18 Drawing Sheets



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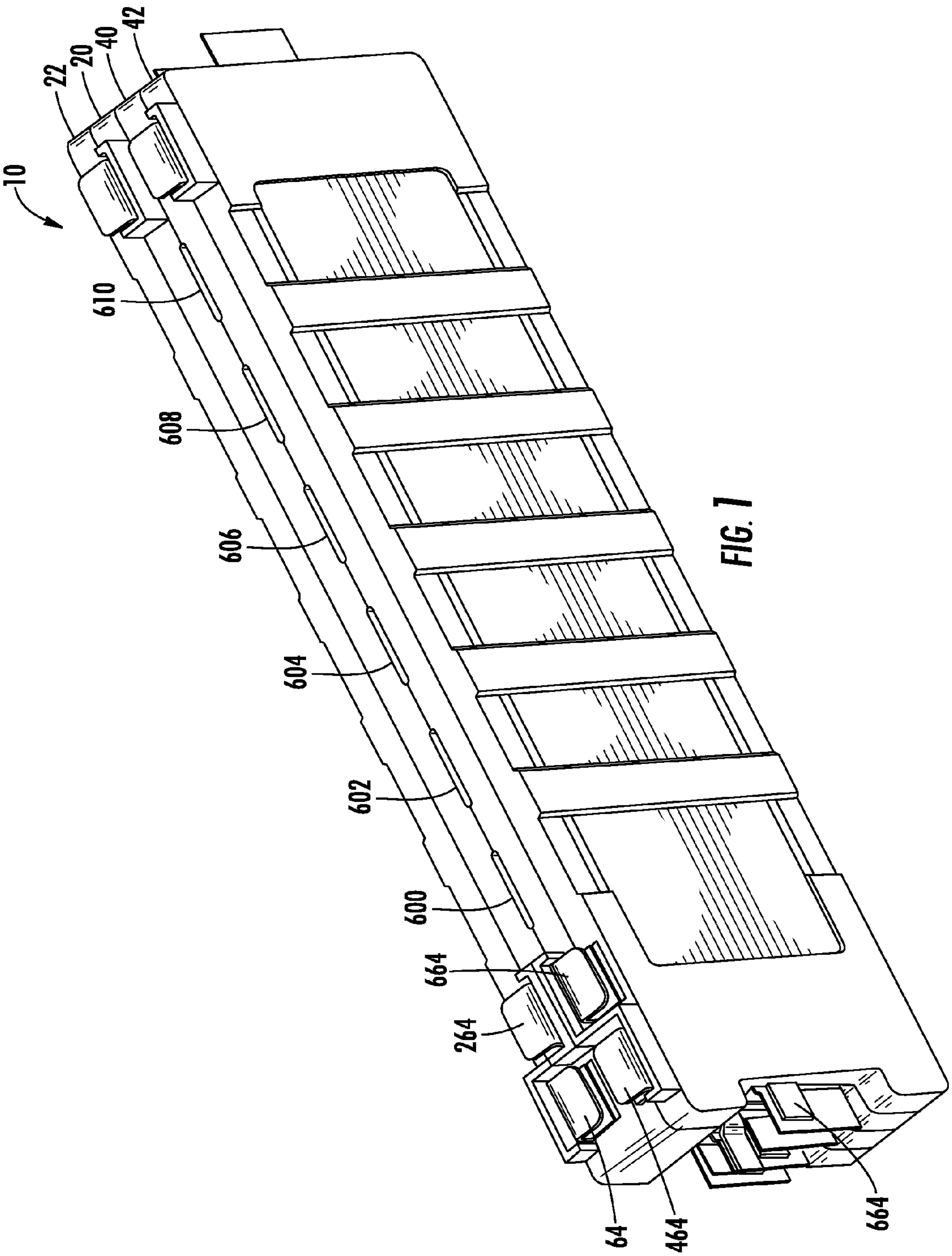

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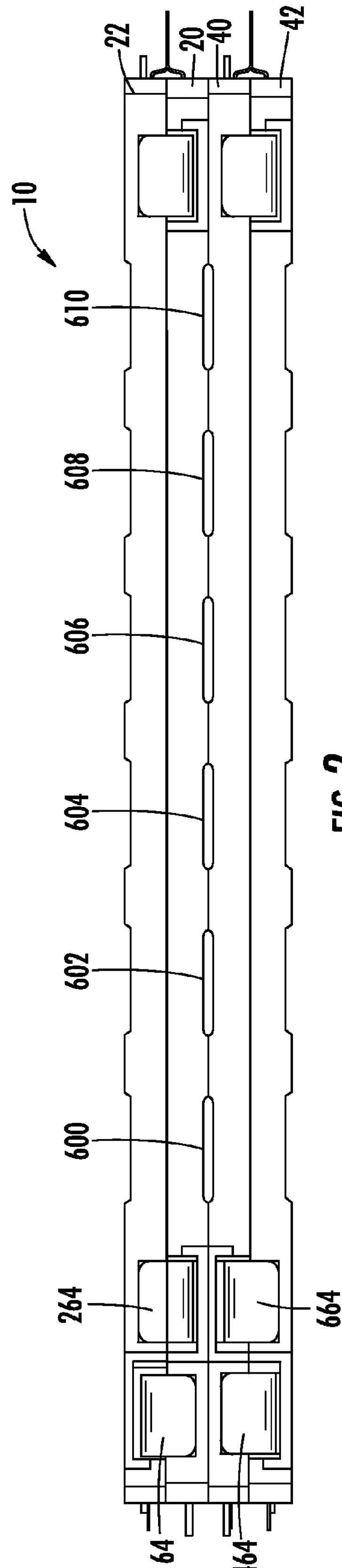

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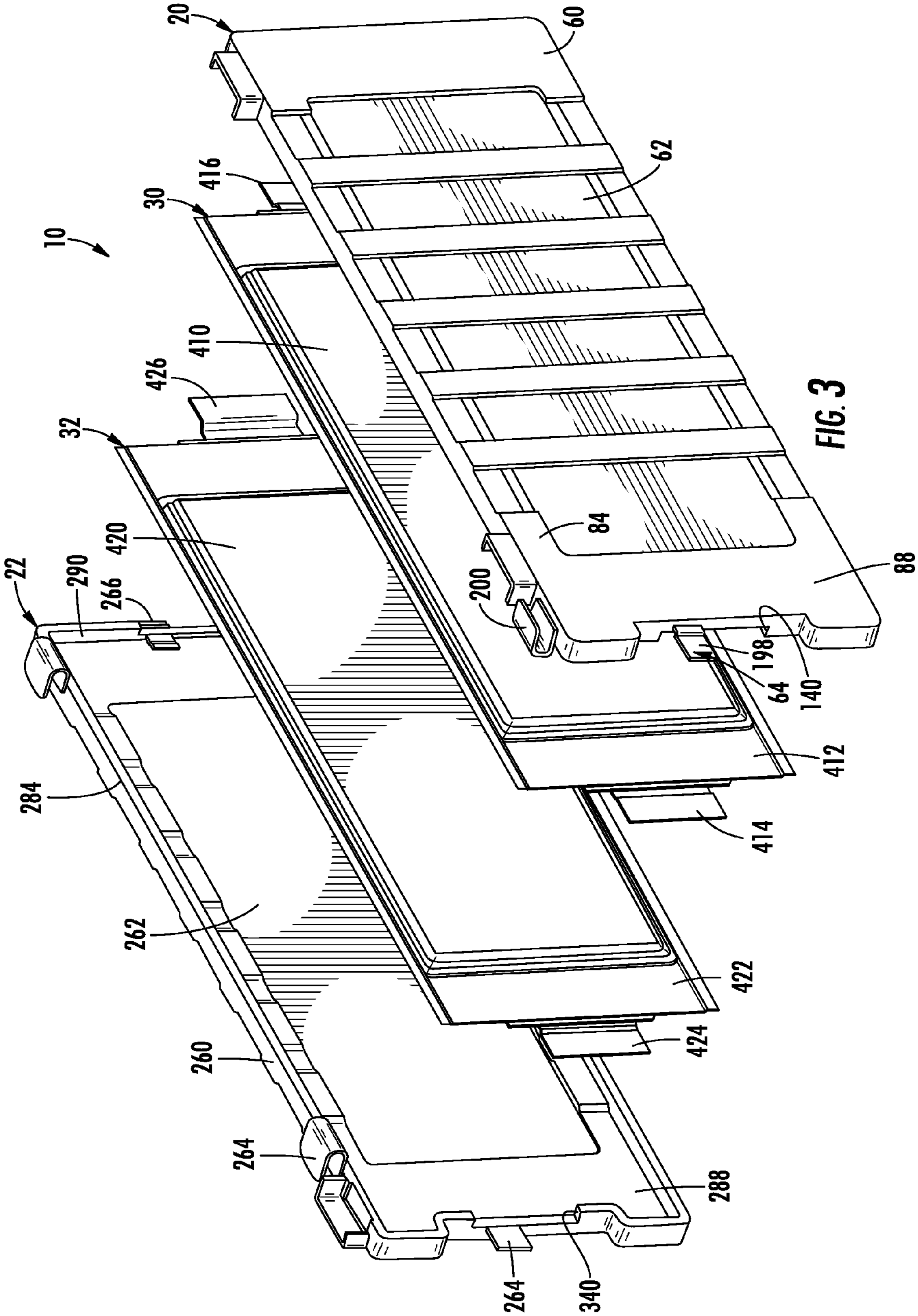
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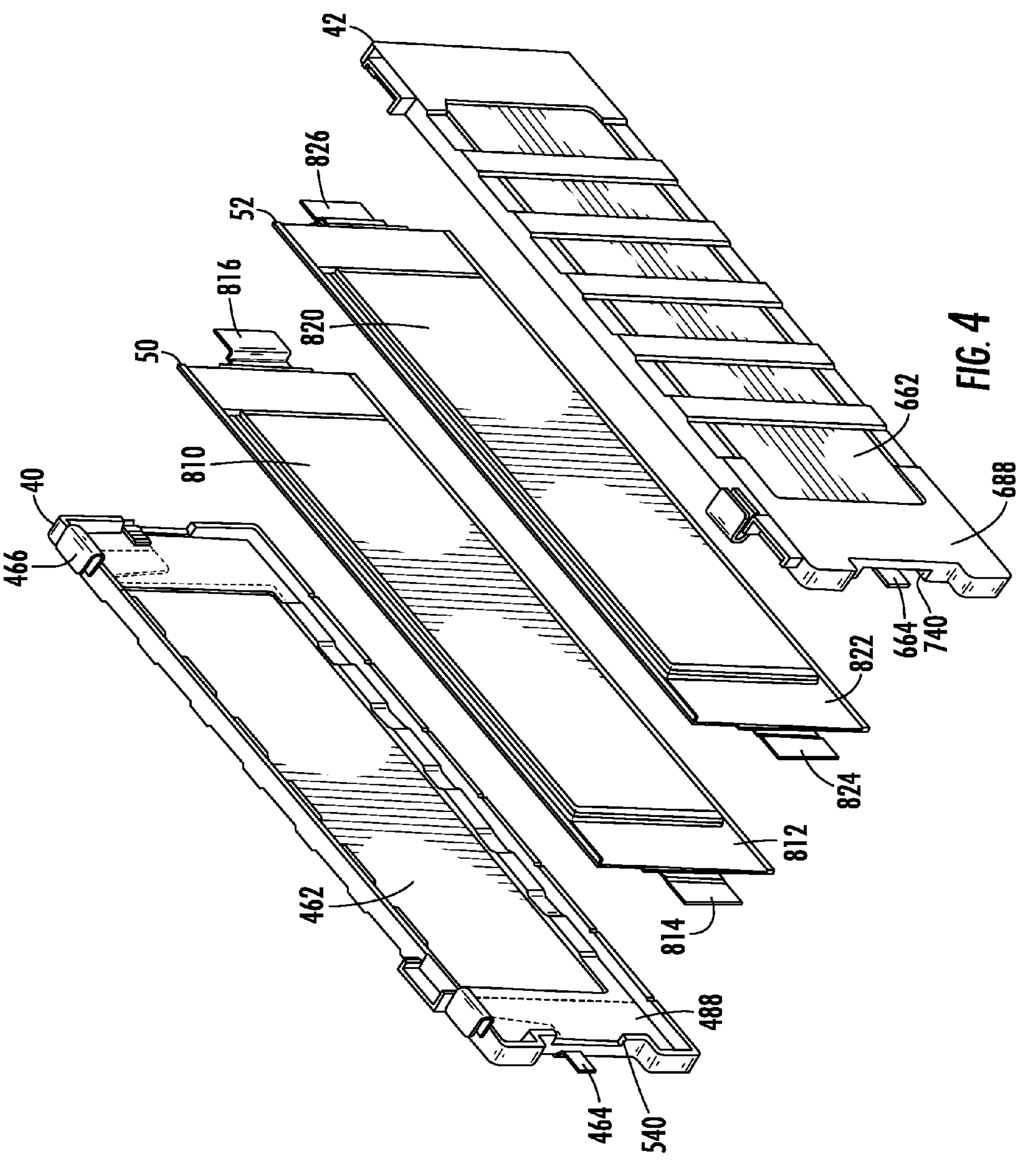
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FIG. 4

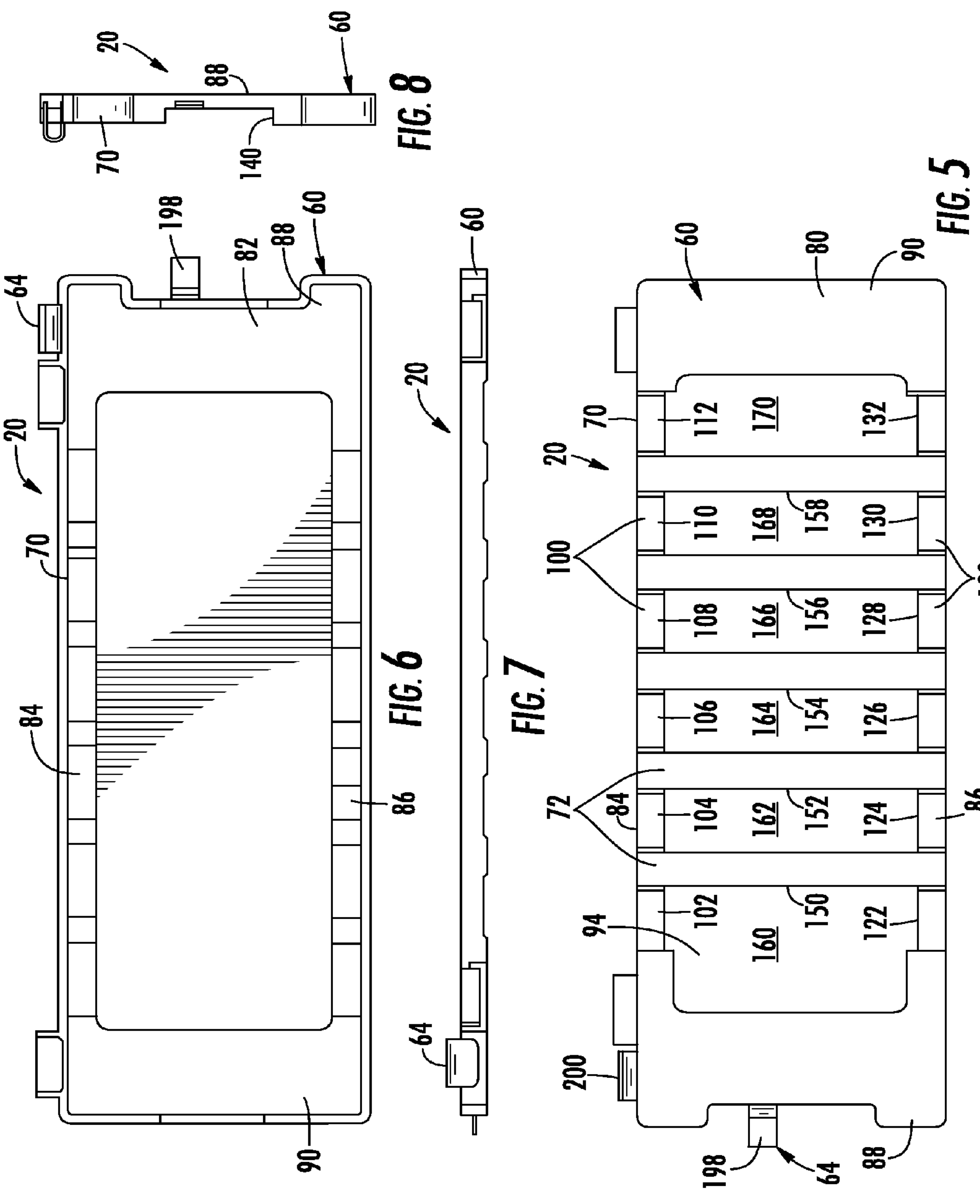


FIG. 8

FIG. 6

FIG. 7

FIG. 5

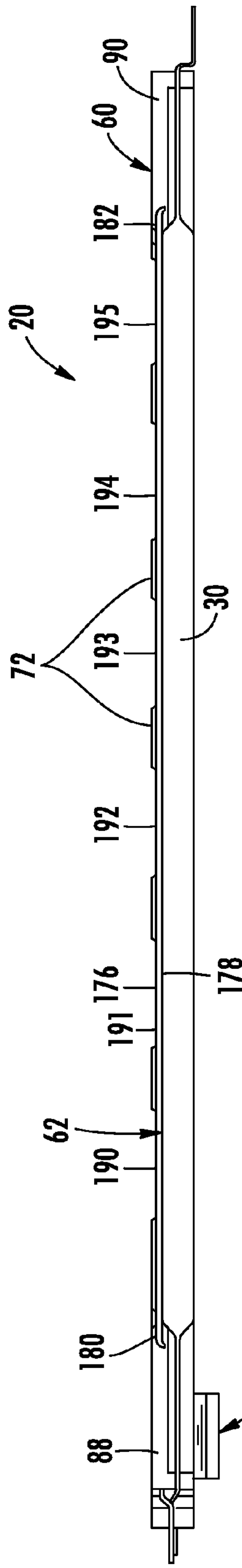


FIG. 9

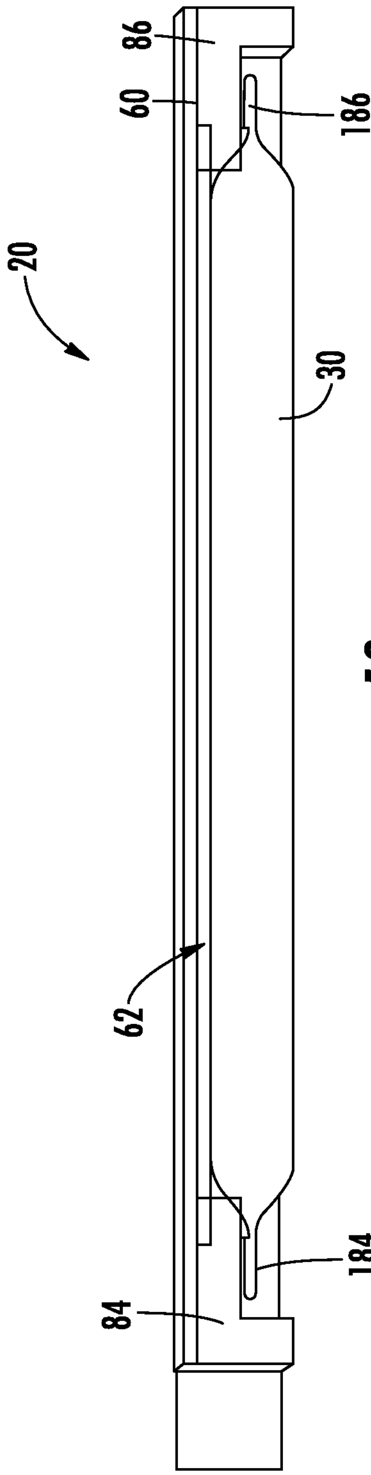
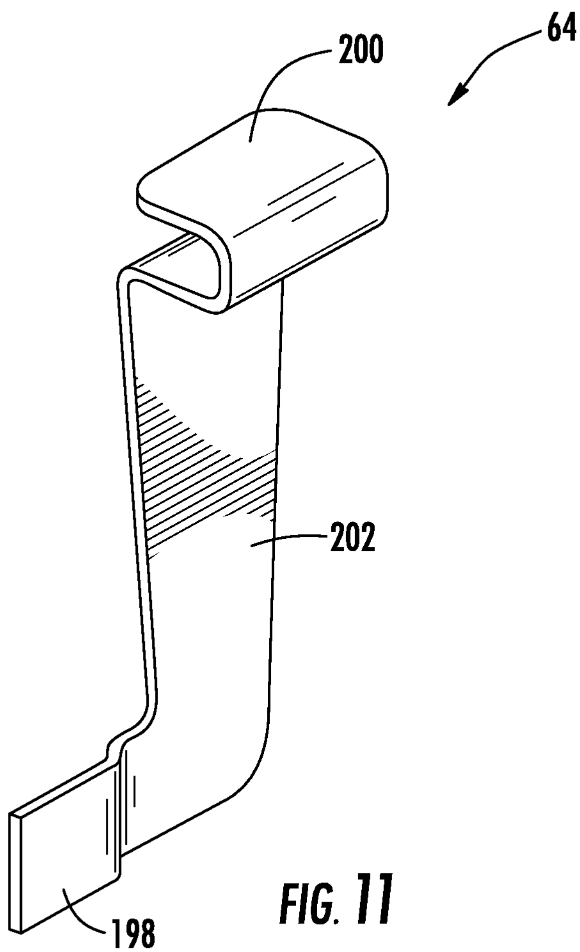


FIG. 10



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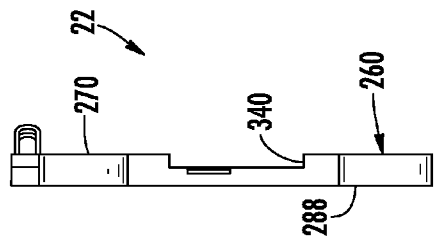

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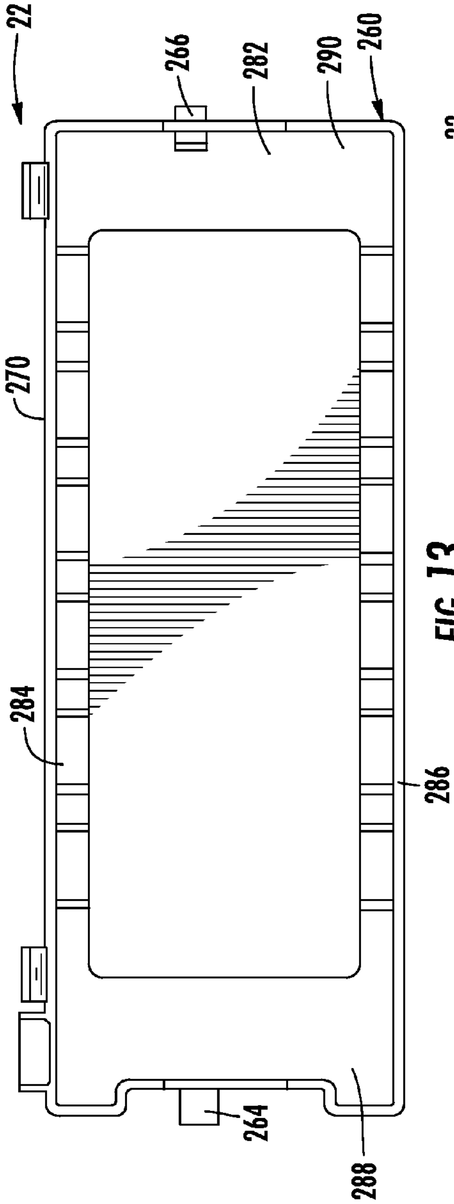

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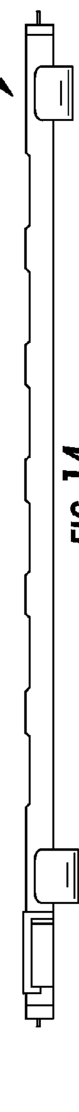


FIG. 14

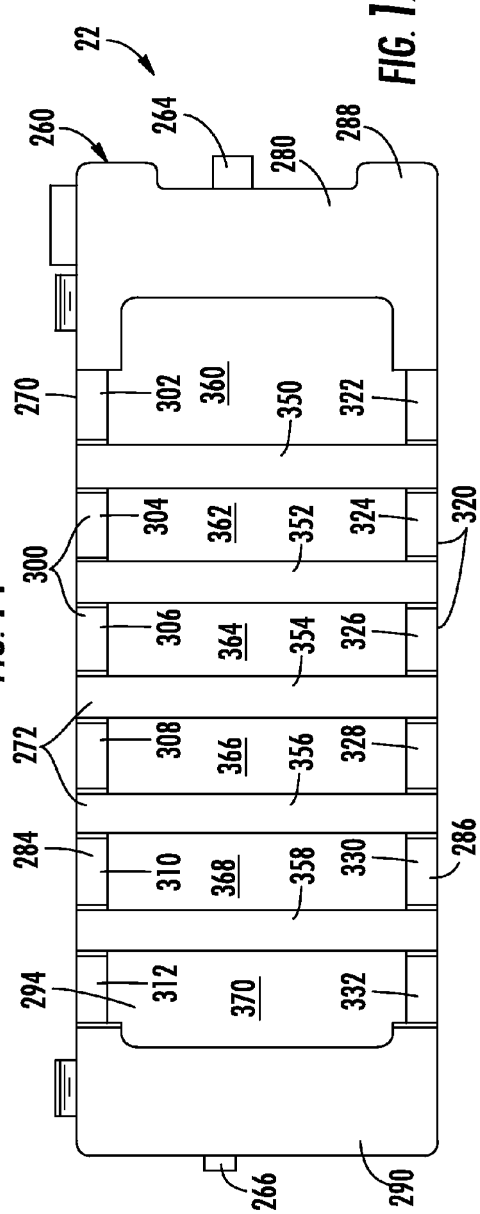


FIG. 12

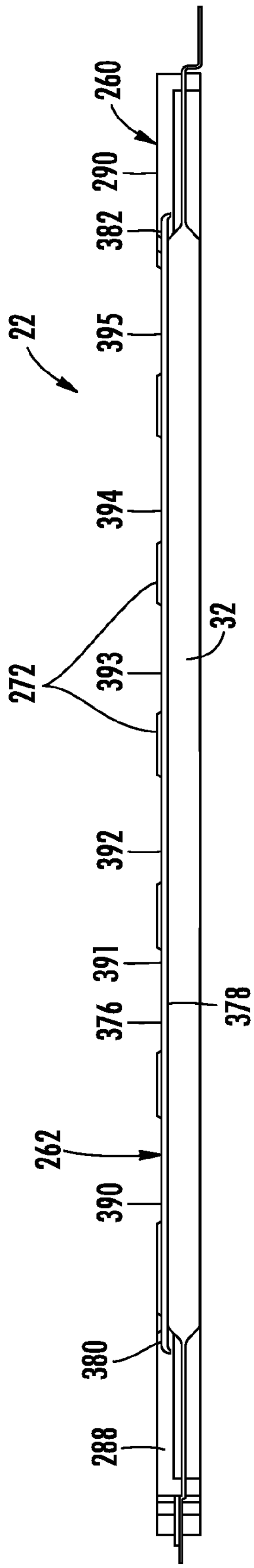


FIG. 16

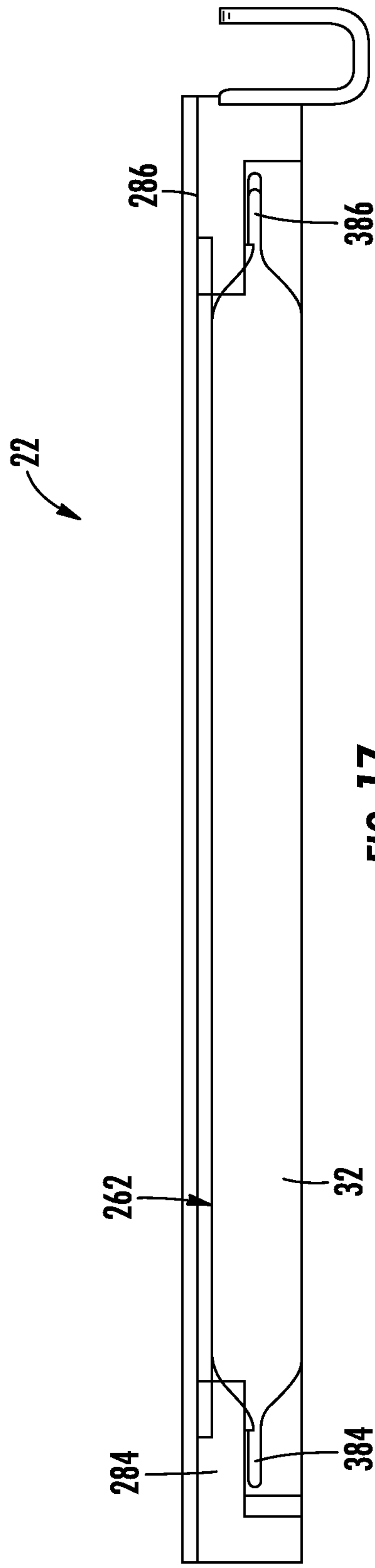


FIG. 17

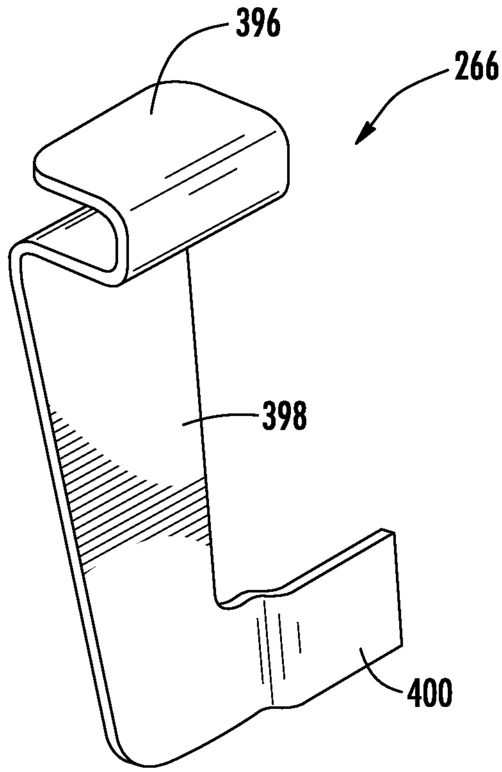


FIG. 18

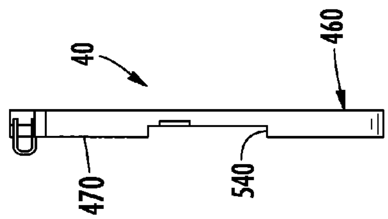


FIG. 22

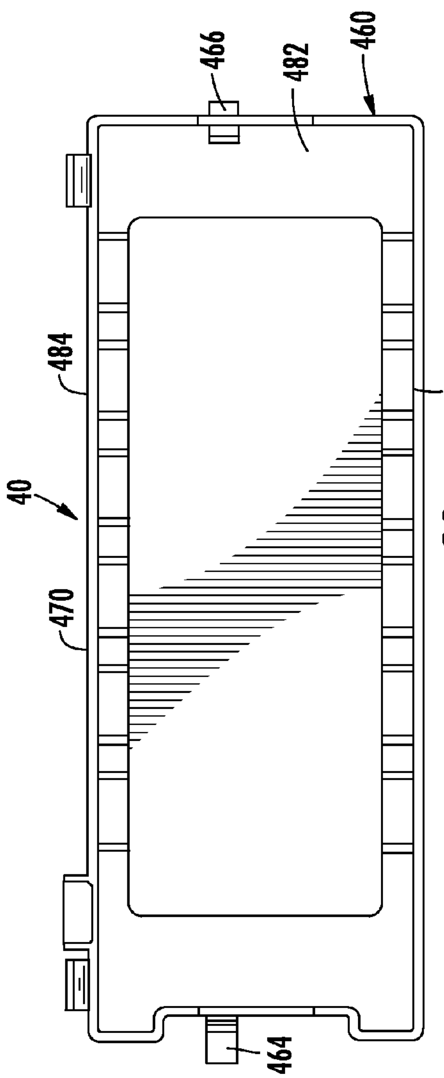


FIG. 20

FIG. 21

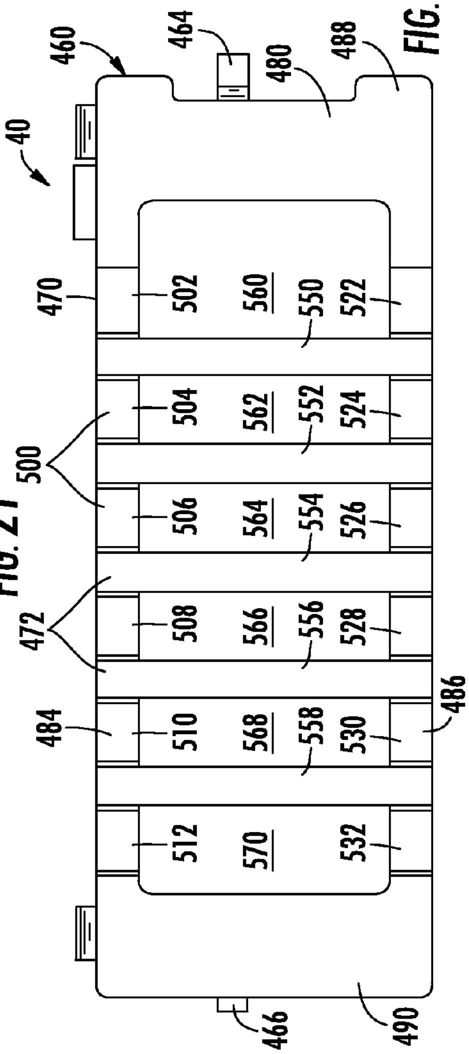


FIG. 19

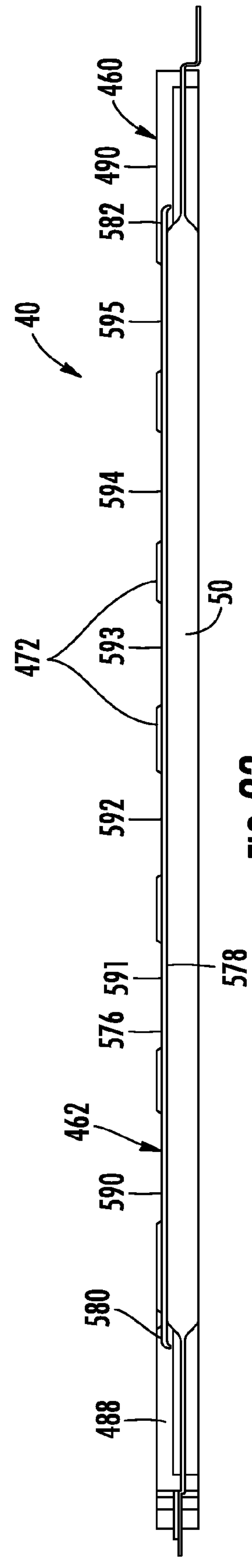


FIG. 23

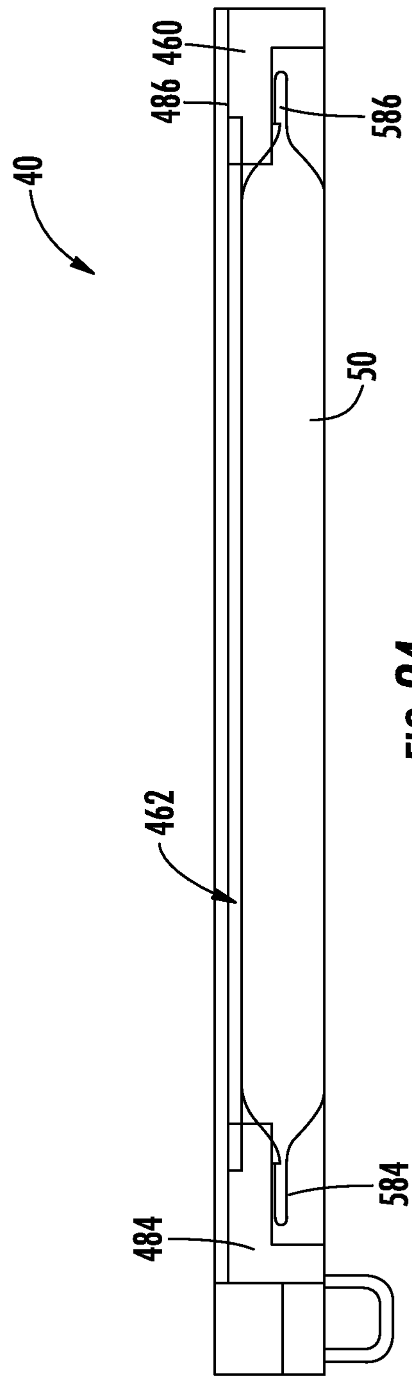


FIG. 24

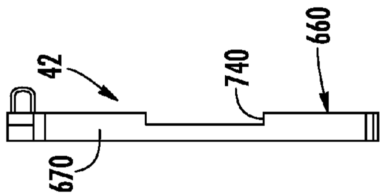


FIG. 28

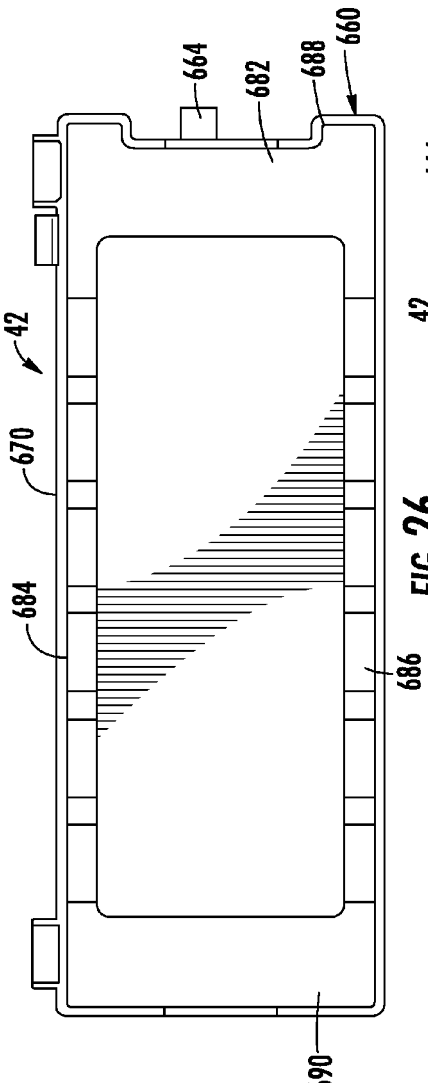
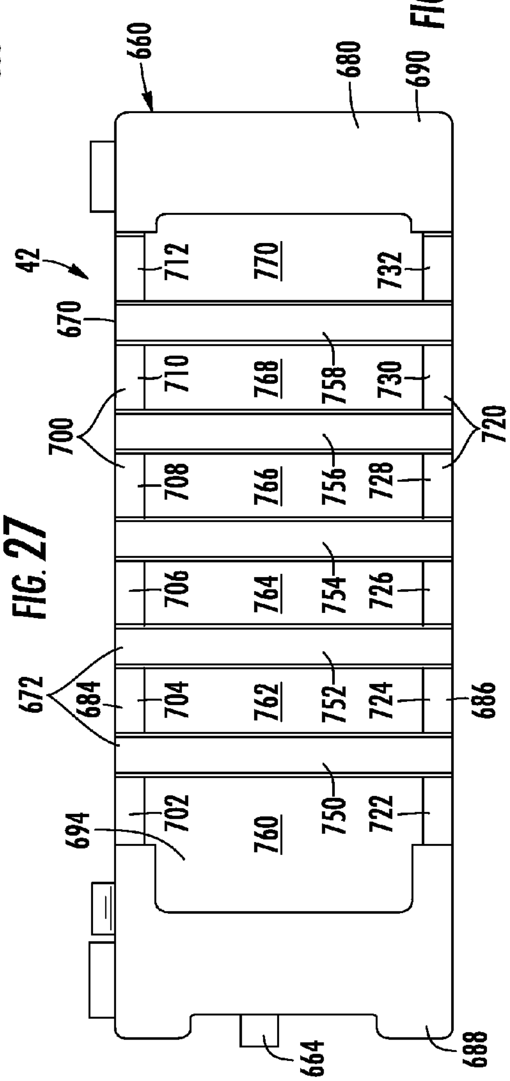


FIG. 26

FIG. 27

FIG. 25



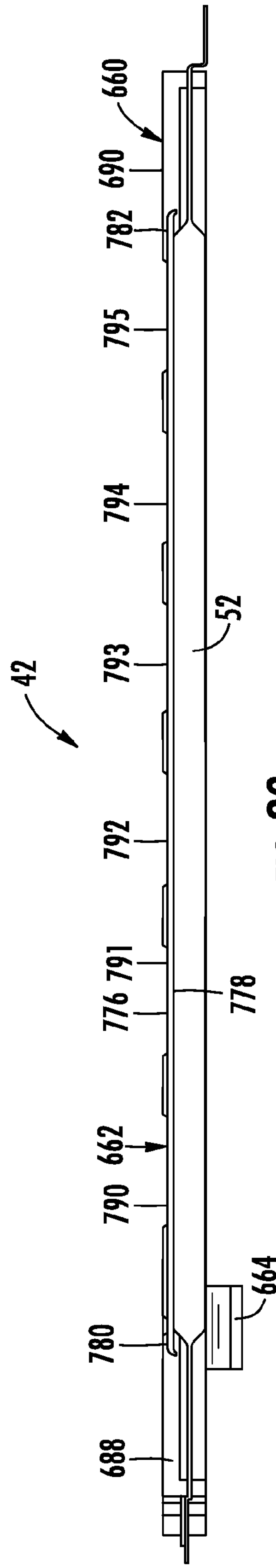


FIG. 29

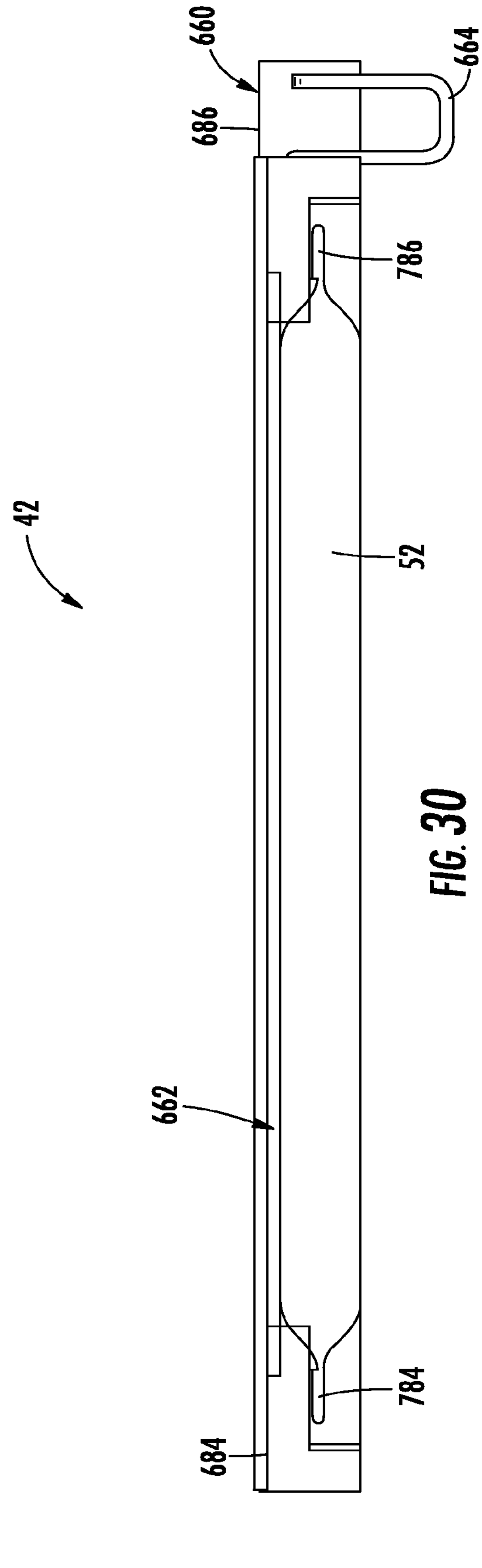


FIG. 30

BATTERY ASSEMBLY

BACKGROUND

The inventors herein have recognized a need for an improved battery assembly that is easier to manufacture and has an improved heat dissipating structure.

SUMMARY

A battery assembly in accordance with an exemplary embodiment is provided. The battery assembly includes a first battery frame assembly having a first plastic frame member and a first thermally conductive plate. The first plastic frame member has a first substantially rectangular ring-shaped peripheral wall and a first plurality of cross-members. The first substantially rectangular ring-shaped peripheral wall has first, second, third and fourth wall portions defining a first central space. The first plurality of cross-members extend between the first and second wall portions and extend across the first central space. The first plurality of cross-members define a first plurality of open spaces therebetween in the first central space. The first substantially rectangular ring-shaped peripheral wall further includes a first plurality of channels extending into the first wall portion proximate to the first plurality of open spaces, and a second plurality of channels extending into the second wall portion proximate to the first plurality of open spaces. The first thermally conductive plate has peripheral edges encapsulated within the first substantially rectangular ring-shaped peripheral wall. The first thermally conductive plate further includes exposed portions disposed in the first plurality of open spaces configured to contact air passing through the first plurality of channels and past the first thermally conductive plate and through the second plurality of channels to extract heat energy from the first thermally conductive plate. The battery assembly further includes a first battery cell configured to contact the first thermally conductive plate. The battery assembly further includes a second battery frame assembly configured to be coupled to the first battery frame assembly such that the first battery cell is disposed between the first and second battery frame assemblies.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic of the battery assembly in accordance with an exemplary embodiment;

FIG. **2** is a side view of the battery assembly of FIG. **1**;

FIG. **3** is an exploded view of a first plastic frame member, a second plastic frame member, a first battery cell, and a second battery cell of the battery assembly of FIG. **1**;

FIG. **4** is an exploded view of a third plastic frame member, a fourth plastic frame member, a third battery cell, and a fourth battery cell of the battery assembly of FIG. **1**;

FIG. **5** is a view of a first side of a first plastic frame member utilized in the battery assembly of FIG. **1**;

FIG. **6** is a view of a second side of the first plastic frame member of FIG. **5**;

FIG. **7** is a side view of the first plastic frame member of FIG. **5**;

FIG. **8** is an end view of the first plastic frame member of FIG. **5**;

FIG. **9** is a cross-sectional view of the first plastic frame member of FIG. **5** and a battery cell;

FIG. **10** is another cross-sectional view of the first plastic frame member of FIG. **5** and a battery cell;

FIG. **11** is a schematic of a bus bar that is partially encapsulated in the first plastic frame member of FIG. **5**;

FIG. **12** is a view of a first side of a second plastic frame member utilized in the battery assembly of FIG. **1**;

FIG. **13** is a view of a second side of the second plastic frame member of FIG. **12**;

FIG. **14** is a side view of the second plastic frame member of FIG. **12**;

FIG. **15** is an end view of the second plastic frame member of FIG. **12**;

FIG. **16** is a cross-sectional view of the second plastic frame member of FIG. **12** and a battery cell;

FIG. **17** is another cross-sectional view of the second plastic frame member of FIG. **12** and a battery cell;

FIG. **18** is a schematic of a current sense member partially encapsulated within the second plastic frame member of FIG. **12**;

FIG. **19** is a view of a first side of a third plastic frame member utilized in the battery assembly of FIG. **1**;

FIG. **20** is a view of a second side of the third plastic frame member of FIG. **19**;

FIG. **21** is a side view of the third plastic frame member of FIG. **19**;

FIG. **22** is an end view of the third plastic frame member of FIG. **19**;

FIG. **23** is a cross-sectional view of the third plastic frame member of FIG. **19** and a battery cell;

FIG. **24** is another cross-sectional view of the third plastic frame member of FIG. **19** and a battery cell;

FIG. **25** is a view of a first side of a fourth plastic frame member utilized in the battery assembly of FIG. **1**;

FIG. **26** is a view of a second side of the fourth plastic frame member of FIG. **25**;

FIG. **27** is a side view of the fourth plastic frame member of FIG. **25**;

FIG. **28** is an end view of the fourth plastic frame member of FIG. **25**;

FIG. **29** is a cross-sectional view of the fourth plastic frame member of FIG. **25** and a battery cell; and

FIG. **30** is another cross-sectional view of the fourth plastic frame member of FIG. **25** and a battery cell.

DETAILED DESCRIPTION

Referring to FIGS. **1-4**, a battery assembly **10** in accordance with an exemplary embodiment is provided. The battery assembly **10** includes battery frame assemblies **20**, **22**, battery cells **30**, **32**, battery frame assemblies **40**, **42**, and battery cells **50**, **52**. An advantage of the battery assembly **10** is that the assembly **10** utilizes a battery frame assembly having a plastic frame member which at least partially encapsulates peripheral edges of a thermally conductive plate therein. As a result, the battery assembly **10** is more easily manufactured than other assemblies, and effectively cools a battery cell disposed against the thermally conductive plate.

The battery frame assemblies **20**, **22** are configured to be coupled together and to hold the battery cells **30**, **32** therebetween.

Referring to FIGS. **5-11**, the battery frame assembly **20** includes a plastic frame member **60**, a thermally conductive plate **62**, and a bus bar **64**. The plastic frame member **60** includes a substantially rectangular ring-shaped peripheral wall **70** and a plurality of cross-members **72**. The substantially rectangular ring-shaped peripheral wall **70** includes a first side **80** and a second side **82**. The wall **70** further includes first, second, third, and fourth wall portions **84**, **86**, **88**, **90** that define a central space **94** therebetween. The first wall portion

84 is substantially parallel to the second wall portion **86**. The third wall portion **88** is substantially parallel to the fourth wall portion **90** and is substantially perpendicular to the first and second wall portions **84**, **86**.

The plurality of cross-members **72** extend between the first and second wall portions **84**, **86** and extend across the central space **94**. The plurality of cross-members **72** include cross-members **150**, **152**, **154**, **156**, **158**. The plurality of cross-members **72** define a plurality of open spaces therebetween in the central space **94**. In particular, the plurality of cross-members **72** define open spaces **160**, **162**, **164**, **166**, **168**, **170** therebetween.

The first wall portion **84** includes a first plurality of channels **100** extending from the first side **80** into the first wall portion **84**. In particular, the first plurality of channels **100** include channels **102**, **104**, **106**, **108**, **110**, **112** extending from the first side **80** into the first wall portion **84** proximate to and fluidly communicating with the open spaces **160**, **162**, **164**, **166**, **168**, **170**, respectively.

The second wall portion **86** includes a second plurality of channels **120** extending from the first side **80** into the second wall portion **86**. In particular, the second plurality of channels **120** include channels **122**, **124**, **126**, **128**, **130**, **132** extending from the first side **80** into the second wall portion **86** proximate to and fluidly communicating with the open spaces **160**, **162**, **164**, **166**, **168**, **170**, respectively.

Referring to FIGS. **3**, **9** and **10**, the thermally conductive plate **62** is configured to extract heat energy from the battery cell **30** disposed against the plate **62** to cool the battery cell **30**. The thermally conductive plate **62** is further configured to transfer the heat energy to air flowing past and contacting the plate **62** that subsequently exits the battery assembly **10**. In one exemplary embodiment, the thermally conductive plate **62** is constructed of steel. In an alternative embodiment, the thermally conductive plate **62** could be constructed of other thermally conductive materials such as copper, aluminum, or stainless steel for example. The thermally conductive plate **62** includes a first side **176**, a second side **178**, and peripheral edges **180**, **182**, **184**, **186**.

The peripheral edges **180**, **182**, **184**, **186** are encapsulated within the substantially rectangular ring-shaped peripheral wall **70**. In particular, referring to FIG. **9**, the peripheral edge **180** is encapsulated within the third wall portion **88**, and the peripheral edge **182** is encapsulated within the fourth wall portion **90**. Further, referring to FIG. **10**, the peripheral edge **184** is encapsulated within the first wall portion **84**, and the peripheral edge **186** is encapsulated within the second wall portion **86**.

Referring to FIGS. **5** and **9**, the thermally conductive plate **62** further includes exposed portions **190**, **191**, **192**, **193**, **194**, **195** disposed in the open spaces **160**, **162**, **164**, **166**, **168**, **170**, respectfully, configured to contact air passing through the channels **102**, **104**, **106**, **108**, **110**, **112**, respectively, and past the thermally conductive plate **62** and through the channels **122**, **124**, **126**, **128**, **130**, **132**, respectively, to extract heat energy from the thermally conductive plate **62**.

Referring to FIGS. **1**, **3**, **5** and **11**, the bus bar **64** is electrically coupled to an electrical terminal **414** of the battery cell **30**. The bus bar **64** has a tab portion **198**, a tab portion **200**, and a central body **202**. The central body **202** is disposed between the tab portions **198**, **200**. The central body **202** is disposed within the first and third wall portions **84**, **88**. The tab portion **198** extends outwardly from the third wall portion **88** and is electrically coupled to the electrical terminal **414** of the battery cell **30**. The tab portion **200** extends outwardly from the first wall portion **84**, and is configured to be welded to a bus bar **464** in the battery frame assembly **40**.

Referring to FIGS. **12-17**, the battery frame assembly **22** includes a plastic frame member **260**, a thermally conductive plate **262**, and a bus bar **264**. The plastic frame member **260** includes a substantially rectangular ring-shaped peripheral wall **270** and a plurality of cross-members **272**. The substantially rectangular ring-shaped peripheral wall **270** includes a first side **280** and a second side **282**. The wall **270** further includes first, second, third, and fourth wall portions **284**, **286**, **288**, **290** that define a central space **294** therebetween. The first wall portion **284** is substantially parallel to the second wall portion **286**. The third wall portion **288** is substantially parallel to the fourth wall portion **290** and is substantially perpendicular to the first and second wall portions **284**, **286**.

The plurality of cross-members **272** extend between the first and second wall portions **284**, **286** and extend across the central space **294**. The plurality of cross-members **272** include cross-members **350**, **352**, **354**, **356**, **358**. The plurality of cross-members **272** define a plurality of open spaces therebetween in the central space **294**. In particular, the plurality of cross-members **272** define open spaces **360**, **362**, **364**, **366**, **368**, **370** therebetween.

The first wall portion **284** includes a first plurality of channels **300** extending from the first side **280** into the first wall portion **284**. In particular, the first plurality of channels **300** include channels **302**, **304**, **306**, **308**, **310**, **312** extending from the first side **280** into the first wall portion **284** proximate to and fluidly communicating with the open spaces **360**, **362**, **364**, **366**, **368**, **370**, respectively.

The second wall portion **286** includes a second plurality of channels **320** extending from the first side **280** into the second wall portion **286**. In particular, the second plurality of channels **320** include channels **322**, **324**, **326**, **328**, **330**, **332** extending from the first side **280** into the second wall portion **286** proximate to and fluidly communicating with the open spaces **360**, **362**, **364**, **366**, **368**, **370**, respectively.

Referring to FIGS. **3**, **16** and **17**, the thermally conductive plate **262** is configured to extract heat energy from the battery cell **32** disposed against the plate **262** to cool the battery cell **32**. The thermally conductive plate **262** is further configured to transfer the heat energy to air flowing past and contacting the plate **262** that subsequently exits the battery assembly **10**. In one exemplary embodiment, the thermally conductive plate **262** is constructed of steel. In an alternative embodiment, the thermally conductive plate **262** could be constructed of other thermally conductive materials such as copper, aluminum, or stainless steel for example. The thermally conductive plate **262** includes a first side **376**, a second side **378**, and peripheral edges **380**, **382**, **384**, **386**.

The peripheral edges **380**, **382**, **384**, **386** are encapsulated within the substantially rectangular ring-shaped peripheral wall **270**. In particular, referring to FIG. **16**, the peripheral edge **380** is encapsulated within the third wall portion **288**, and the peripheral edge **382** is encapsulated within the fourth wall portion **290**. Further, referring to FIG. **17**, the peripheral edge **384** is encapsulated within the first wall portion **284**, and the peripheral edge **386** is encapsulated within the second wall portion **286**.

Referring to FIGS. **12** and **16**, the thermally conductive plate **262** further includes exposed portions **390**, **391**, **392**, **393**, **394**, **395** disposed in the open spaces **360**, **362**, **364**, **366**, **368**, **370**, respectfully, configured to contact air passing through the channels **302**, **304**, **306**, **308**, **310**, **312**, respectively, and past the thermally conductive plate **262** and through the channels **322**, **324**, **326**, **328**, **330**, **332**, respectively, to extract heat energy from the thermally conductive plate **262**.

Referring to FIGS. **3** and **12**, the bus bar **264** is electrically coupled to an electrical terminal **424** of the battery cell **32**. The bus bar **264** has a structure identical to a structure of the bus bar **64** described above. A tab of the bus bar **264** is configured to be welded to another bus bar (not shown) in another battery frame assembly.

Referring to FIGS. **3** and **18**, the current sense member **266** is electrically coupled to an electrical terminal **426** of the battery cell **32**. The current sense member **266** has a current sense lead **396**, a central body **398**, and a current sense lead **400**. The central body **398** is disposed between the current sense leads **396**, **400**. The central body **398** is disposed within the first and fourth wall portions **284**, **290**. The current sense lead **400** extends outwardly from the fourth wall portion **290** and is electrically coupled to the electrical terminal **426** of the battery cell **32**. Also, the current sense lead **396** extends outwardly from the first wall portion **284** and is configured to be welded to another current sense lead (not shown).

Referring to FIGS. **3** and **6**, the battery cell **30** is disposed against the second side **82** of the substantially rectangular ring-shaped peripheral wall **70** of the plastic frame member **60**. The battery cell **30** includes a body portion **410**, a peripheral lip portion **412**, and electrical terminals **414**, **416**. The peripheral lip portion **412** extends around a periphery of the body portion **410**. The electrical terminal **414** extends outwardly from a first end of the peripheral lip portion **412** and is electrically coupled to an active element within the body portion **410**. The electrical terminal **414** further extends through an aperture formed by the adjacent channels **140**, **340** formed in the battery frame assemblies **20**, **22**, respectively. The electrical terminal **416** extends outwardly from a second end of the peripheral lip portion **412** and is electrically coupled to the active element within the body portion **410**. The electrical terminal **416** further extends through an aperture formed by the adjacent channels formed in the battery frame assemblies **20**, **22**, respectively. The electrical terminal **414** is electrically coupled to the bus bar **64**. The electrical terminal **416** is electrically coupled to the electrical terminal **426** of the battery cell **32**. During operation, the battery cell **30** generates a voltage between the electrical terminals **414**, **416**. Further, during operation, the body portion **410** contacts the thermally conductive plate **62** which extracts heat energy from the body portion **410** of the battery cell **30** to cool the battery cell **30**. In an exemplary embodiment, the battery cell **30** is a lithium-ion pouch-type battery cell. Of course, in an alternative embodiment, the battery cell **30** could be another type of battery cell such as a nickel metal hydride battery cell for example.

Referring to FIGS. **3** and **13**, the battery cell **32** is disposed against the second side **282** of the substantially rectangular ring-shaped peripheral wall **270** of the plastic frame member **260**. The battery cell **32** includes a body portion **420**, a peripheral lip portion **422**, and electrical terminals **424**, **426**. The peripheral lip portion **422** extends around a periphery of the body portion **420**. The electrical terminal **424** extends outwardly from a first end of the peripheral lip portion **422** and is electrically coupled to an active element within the body portion **420**. The electrical terminal **424** further extends through an aperture formed by the adjacent channels **140**, **340** formed in the battery frame assemblies **20**, **22**, respectively. The electrical terminal **426** extends outwardly from a second end of the peripheral lip portion **422** and is electrically coupled to the active element within the body portion **420**. The electrical terminal **426** further extends through an aperture formed by the adjacent channels formed in the battery frame assemblies **20**, **22**, respectively. The electrical terminal **424** is electrically coupled to the bus bar **264**. The electrical terminal **426** is electrically coupled to the electrical terminal **416** of the battery cell **30**. During operation, the battery cell **32** generates a voltage between the electrical terminals **424**, **426**. Further, during operation, the body portion **420** contacts the thermally conductive plate **262** which extracts heat energy from the body portion **420** of the battery cell **32** to cool the battery cell **32**. In an exemplary embodiment, the battery cell **32** is a lithium-ion pouch-type battery cell. Of course, in an alternative embodiment, the battery cell **32** could be another type of battery cell such as a nickel metal hydride battery cell for example.

The battery frame assemblies **40**, **42** are configured to be coupled together and to hold the battery cells **50**, **52** therebetween.

Referring to FIGS. **4** and **19-24**, the battery frame assembly **40** includes a plastic frame member **460**, a thermally conductive plate **462**, and a bus bar **464**. The plastic frame member **460** includes a substantially rectangular ring-shaped peripheral wall **470** and a plurality of cross-members **472**. The substantially rectangular ring-shaped peripheral wall **470** includes a first side **480** and a second side **482**. The wall **470** further includes first, second, third, and fourth wall portions **484**, **486**, **488**, **490** that define a central space **494** therebetween. The first wall portion **484** is substantially parallel to the second wall portion **486**. The third wall portion **488** is substantially parallel to the fourth wall portion **490** and is substantially perpendicular to the first and second wall portions **484**, **486**.

The plurality of cross-members **472** extend between the first and second wall portions **484**, **486** and extend across the central space **494**. The plurality of cross-members **472** include cross-members **550**, **552**, **554**, **556**, **558**. The plurality of cross-members **472** define a plurality of open spaces therebetween in the central space **494**. In particular, the plurality of cross-members **472** define open spaces **560**, **562**, **564**, **566**, **568**, **570** therebetween.

The first wall portion **484** includes a first plurality of channels **500** extending from the first side **480** into the first wall portion **484**. In particular, the first plurality of channels **500** include channels **502**, **504**, **506**, **508**, **510**, **512** extending from the first side **480** into the first wall portion **484** proximate to and fluidly communicating with the open spaces **560**, **562**, **564**, **566**, **568**, **570**, respectively.

The second wall portion **486** includes a second plurality of channels **520** extending from the first side **480** into the second wall portion **486**. In particular, the second plurality of channels **520** include channels **522**, **524**, **526**, **528**, **530**, **532** extending from the first side **480** into the second wall portion **486** proximate to and fluidly communicating with the open spaces **560**, **562**, **564**, **566**, **568**, **570**, respectively.

Referring to FIGS. **4**, **23** and **24**, the thermally conductive plate **462** is configured to extract heat energy from the battery cell **50** disposed against the plate **462** to cool the battery cell **50**. The thermally conductive plate **462** is further configured to transfer the heat energy to air flowing past and contacting the plate **462** that subsequently exits the battery assembly **10**. In one exemplary embodiment, the thermally conductive plate **462** is constructed of steel. In an alternative embodiment, the thermally conductive plate **462** could be constructed of other thermally conductive materials such as copper, aluminum, or stainless steel for example. The thermally conductive plate **462** includes a first side **576**, a second side **578**, and peripheral edges **580**, **582**, **584**, **586**.

The peripheral edges **580**, **582**, **584**, **586** are encapsulated within the substantially rectangular ring-shaped peripheral wall **470**. In particular, referring to FIG. **23**, the peripheral edge **580** is encapsulated within the third wall portion **488**, and the peripheral edge **582** is encapsulated within the fourth wall portion **490**. Further, referring to FIG. **24**, the peripheral edge **584** is encapsulated within the first wall portion **484**, and the peripheral edge **586** is encapsulated within the second wall portion **486**.

Referring to FIGS. **19** and **23**, the thermally conductive plate **462** further includes exposed portions **590**, **591**, **592**, **593**, **594**, **595** disposed in the open spaces **560**, **562**, **564**, **566**, **568**, **570**, respectfully, configured to contact air passing through the channels **502**, **504**, **506**, **508**, **510**, **512**, respectively, and past the thermally conductive plate **462** and through the channels **522**, **524**, **526**, **528**, **530**, **532**, respectively, to extract heat energy from the thermally conductive plate **462**.

Referring to FIGS. **1**, **4** and **19**, the bus bar **464** is electrically coupled to an electrical terminal **814** of the battery cell **50**. The bus bar **464** has a structure identical to a structure of the bus bar **64** described above. A tab of the bus bar **464** is configured to be welded to the bus bar **64** of the battery frame assembly **20**.

Referring to FIG. **4**, the current sense member **466** is electrically coupled to an electrical terminal **816** of the battery cell **50**. The structure of the current sense member **466** is identical to a structure of the current sense member **266** discussed above.

Referring to FIGS. **1**, **2**, **4** and **5**, the battery frame assemblies **20**, **40** define the flow paths **600**, **602**, **604**, **606**, **608**, **610** therethrough for receiving air that flows through the flow paths to extract heat energy from the thermally conductive plates **62**, **462**.

The flow path **600** is defined by the channel **102**, the exposed portion **190** in the open space **160**, the channel **122** of the battery frame assembly **20**. The flow path **600** is further defined by the channel **502**, the exposed portion **590** in the open space **560**, the channel **522** of the battery frame assembly **40**.

The flow path **602** is defined by the channel **104**, the exposed portion **191** in the open space **162**, the channel **124** of the battery frame assembly **20**. The flow path **602** is further defined by the channel **504**, the exposed portion **591** in the open space **562**, the channel **524** of the battery frame assembly **40**.

The flow path **604** is defined by the channel **106**, the exposed portion **192** in the open space **164**, the channel **126** of the battery frame assembly **20**. The flow path **604** is further defined by the channel **506**, the exposed portion **592** in the open space **564**, the channel **526** of the battery frame assembly **40**.

The flow path **606** is defined by the channel **108**, the exposed portion **193** in the open space **166**, the channel **128** of the battery frame assembly **20**. The flow path **606** is further defined by the channel **508**, the exposed portion **593** in the open space **566**, the channel **528** of the battery frame assembly **40**.

The flow path **608** is defined by the channel **110**, the exposed portion **194** in the open space **168**, the channel **130** of the battery frame assembly **20**. The flow path **608** is further defined by the channel **510**, the exposed portion **594** in the open space **568**, the channel **530** of the battery frame assembly **40**.

The flow path **610** is defined by the channel **112**, the exposed portion **195** in the open space **170**, the channel **132** of the battery frame assembly **20**. The flow path **610** is further defined by the channel **512**, the exposed portion **595** in the open space **570**, the channel **532** of the battery frame assembly **40**.

Referring to FIGS. **1**, **4** and **25-30**, the battery frame assembly **42** includes a plastic frame member **660**, a thermally conductive plate **662**, and a bus bar **664**. The plastic frame member **660** includes a substantially rectangular ring-shaped peripheral wall **670** and a plurality of cross-members **672**. The substantially rectangular ring-shaped peripheral wall **670** includes a first side **680** and a second side **682**. The wall **670** further includes first, second, third, and fourth wall portions **684**, **686**, **688**, **690** that define a central space **694** therebetween. The first wall portion **684** is substantially parallel to the second wall portion **686**. The third wall portion **688** is substantially parallel to the fourth wall portion **690** and is substantially perpendicular to the first and second wall portions **684**, **686**.

The plurality of cross-members **672** extend between the first and second wall portions **684**, **686** and extend across the central space **694**. The plurality of cross-members **672** include cross-members **750**, **752**, **754**, **756**, **758**. The plurality of cross-members **672** define a plurality of open spaces therebetween in the central space **694**. In particular, the plurality of cross-members **672** define open spaces **760**, **762**, **764**, **766**, **768**, **770** therebetween.

The first wall portion **684** includes a first plurality of channels **700** extending from the first side **680** into the first wall portion **684**. In particular, the first plurality of channels **700** include channels **702**, **704**, **706**, **708**, **710**, **712** extending from the first side **680** into the first wall portion **684** proximate to and fluidly communicating with the open spaces **760**, **762**, **764**, **766**, **768**, **770**, respectively.

The second wall portion **686** includes a second plurality of channels **720** extending from the first side **680** into the second wall portion **686**. In particular, the second plurality of channels **720** include channels **722**, **724**, **726**, **728**, **730**, **732** extending from the first side **680** into the second wall portion **686** proximate to and fluidly communicating with the open spaces **760**, **762**, **764**, **766**, **768**, **770**, respectively.

Referring to FIGS. **4**, **29** and **30**, the thermally conductive plate **662** is configured to extract heat energy from the battery cell **52** disposed against the plate **662** to cool the battery cell **52**. The thermally conductive plate **662** is further configured to transfer the heat energy to air flowing past and contacting the plate **662** that subsequently exits the battery assembly **10**. In one exemplary embodiment, the thermally conductive plate **662** is constructed of steel. In an alternative embodiment, the thermally conductive plate **662** could be constructed of other thermally conductive materials such as copper, aluminum, or stainless steel for example. The thermally conductive plate **662** includes a first side **776**, a second side **778**, and peripheral edges **780**, **782**, **784**, **786**.

The peripheral edges **780**, **782**, **784**, **786** are encapsulated within the substantially rectangular ring-shaped peripheral wall **670**. In particular, referring to FIG. **29**, the peripheral edge **780** is encapsulated within the third wall portion **688**, and the peripheral edge **782** is encapsulated within the fourth wall portion **690**. Further, referring to FIG. **30**, the peripheral edge **784** is encapsulated within the first wall portion **684**, and the peripheral edge **786** is encapsulated within the second wall portion **686**.

Referring to FIGS. **25** and **29**, the thermally conductive plate **662** further includes exposed portions **790**, **791**, **792**, **793**, **794**, **795** disposed in the open spaces **760**, **762**, **764**, **766**, **768**, **770**, respectfully, configured to contact air passing through the channels **702**, **704**, **706**, **708**, **710**, **712**, respectively, and past the thermally conductive plate **662** and through the channels **722**, **724**, **726**, **728**, **730**, **732**, respectively, to extract heat energy from the thermally conductive plate **662**.

Referring to FIGS. **1** and **4**, the bus bar **664** is electrically coupled to an electrical terminal **824** of the battery cell **52**. The bus bar **664** has a structure identical to a structure of the bus bar **64** described above. A tab of the bus bar **664** is configured to be welded to another bus bar of another battery frame assembly.

Referring to FIGS. **4** and **20**, the battery cell **50** is disposed against the second side **482** of the substantially rectangular ring-shaped peripheral wall **470** of the plastic frame member **460**. The battery cell **50** includes a body portion **810**, a peripheral lip portion **812**, and electrical terminals **814**, **816**. The peripheral lip portion **812** extends around a periphery of the body portion **810**. The electrical terminal **814** extends outwardly from a first end of the peripheral lip portion **812** and is electrically coupled to an active element within the body portion **810**. The electrical terminal **814** further extends through an aperture formed by the adjacent channels **540**, **740** formed in the battery frame assemblies **40**, **42**, respectively. The electrical terminal **816** extends outwardly from a second end of the peripheral lip portion **812** and is electrically coupled to the active element within the body portion **810**. The electrical terminal **816** further extends through an aperture formed by the adjacent channels formed in the battery frame assemblies **40**, **42**, respectively. The electrical terminal **814** is electrically coupled to the bus bar **464**. The electrical terminal **816** is electrically coupled to the electrical terminal **826** of the battery cell **52**. During operation, the battery cell **50** generates a voltage between the electrical terminals **814**, **816**. Further, during operation, the body portion **810** contacts the thermally conductive plate **462** which extracts heat energy from the body portion **810** of the battery cell **50** to cool the battery cell **50**. In an exemplary embodiment, the battery cell **50** is a lithium-ion pouch-type battery cell. Of course, in an alternative embodiment, the battery cell **50** could be another type of battery cell such as a nickel metal hydride battery cell for example.

Referring to FIGS. **4** and **26**, the battery cell **52** is disposed against the second side **682** of the substantially rectangular ring-shaped peripheral wall **670** of the plastic frame member **660**. The battery cell **52** includes a body portion **820**, a peripheral lip portion **822**, and electrical terminals **824**, **826**. The peripheral lip portion **822** extends around a periphery of the body portion **820**. The electrical terminal **824** extends outwardly from a first end of the peripheral lip portion **822** and is electrically coupled to an active element within the body portion **820**. The electrical terminal **824** further extends through an aperture formed by the adjacent channels **540**, **740** formed in the battery frame assemblies **40**, **42**, respectively. The electrical terminal **826** extends outwardly from a second end of the peripheral lip portion **822** and is electrically coupled to the active element within the body portion **820**. The electrical terminal **826** further extends through an aperture formed by the adjacent channels formed in the battery frame assemblies **40**, **42**, respectively. The electrical terminal **824** is electrically coupled to the bus bar **664**. The electrical terminal **826** is electrically coupled to the electrical terminal **816** of the battery cell **50**. During operation, the battery cell **52** generates a voltage between the electrical terminals **824**, **826**. Further, during operation, the body portion **820** contacts the thermally conductive plate **662** which extracts heat energy from the body portion **820** of the battery cell **52** to cool the battery cell **52**. In an exemplary embodiment, the battery cell **52** is a lithium-ion pouch-type battery cell. Of course, in an alternative embodiment, the battery cell **52** could be another type of battery cell such as a nickel metal hydride battery cell for example.

The battery assembly provides a substantial advantage over other battery assemblies. In particular, the battery assembly utilizes a battery frame assembly having a plastic frame member which at least partially encapsulates peripheral edges of a thermally conductive plate therein. As a result, the battery assembly **10** is more easily manufactured than other assemblies, and effectively cools a battery cell disposed against the thermally conductive plate.

While the claimed invention has been described in detail in connection with only a limited number of embodiments, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the claimed invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. Additionally, while various embodiments of the claimed invention have been described, it is to be understood that aspects of the invention may include only some of the described embodiments. Accordingly, the claimed invention is not to be seen as limited by the foregoing description.

What is claimed is:

1. A battery assembly, comprising:

a first battery frame assembly having a first plastic frame member and a first thermally conductive plate;

the first plastic frame member having a first substantially rectangular ring-shaped peripheral wall and a first plurality of cross-members; the first substantially rectangular ring-shaped peripheral wall having first, second, third and fourth wall portions defining a first central space, the first plurality of cross-members extending between the first and second wall portions and extending across the first central space, the first plurality of cross-members defining a first plurality of open spaces therebetween in the first central space; the first substantially rectangular ring-shaped peripheral wall further having a first plurality of channels extending into the first wall portion proximate to the first plurality of open spaces, and a second plurality of channels extending into the second wall portion proximate to the first plurality of open spaces;

the first thermally conductive plate having first, second, third and fourth peripheral edges being disposed and encapsulated within the first, second, third and fourth wall portions, respectively, of the first substantially rectangular ring-shaped peripheral wall, the first thermally conductive plate having first and second sides, the first plurality of cross-members being disposed directly on an contacting the first side of the first thermally conductive plate, the first thermally conductive plate further having exposed portions on the first side thereof disposed in the first plurality of open spaces configured to contact air flowing through the first plurality of channels and past the first side of the first thermally conductive plate and through the second plurality of channels to extract heat energy from the first thermally conductive plate;

a first battery cell being disposed directly on and contacting the second side of the first thermally conductive plate;

a second battery cell being disposed directly on and contacting the first battery cell;

a second battery frame assembly being coupled to the first battery frame assembly such that the first and second battery cells are disposed between the first and second battery frame assemblies, the second battery frame assembly having a second plastic frame member and a second thermally conductive plate, the second thermally conductive plate having first, second, third and fourth peripheral edges disposed and encapsulated within the second plastic frame member, the second thermally conductive plate having first and second sides, the first side of the second thermally conductive plate being disposed directly on and contacting the second battery cell such that the first and second battery cells are disposed directly between the first and second thermally conductive plates; and

a second plurality of cross-members of the second plastic frame member being disposed directly on and contacting the second side of the second thermally conductive plate.

2. The battery assembly of claim **1**, wherein

the first and second battery cells are further disposed between the first battery frame assembly and the second battery frame assembly, the first plastic frame member being coupled to the second plastic frame member.

3. The battery assembly of claim **1**, wherein the second plastic frame member further includes a second substantially rectangular ring-shaped peripheral wall; the second substantially rectangular ring-shaped peripheral wall having first, second, third and fourth wall portions defining a second central space, the second plurality of cross-members extending between the first and second wall portions of the second substantially rectangular ring-shaped peripheral wall and extending across the second central space, the second plurality of cross-members defining a second plurality of open spaces therebetween in the second central space, the second substantially rectangular ring-shaped peripheral wall further having a first plurality of channels extending into the first wall portion thereof proximate to the second plurality of open spaces, and a second plurality of channels extending into the second wall portion thereof proximate to the second plurality of open spaces.

4. The battery assembly of claim **3**, wherein the second thermally conductive plate further having exposed portions disposed in the second plurality of open spaces configured to contact air passing through the first plurality of channels in the first wall portion of the second substantially rectangular ring-shaped peripheral wall and past the second thermally conductive plate and through the second plurality of channels in the second wall portion of the second substantially rectangular ring-shaped peripheral wall to extract heat energy from the second thermally conductive plate.

5. The battery assembly of claim **3**, further comprising:

a first bus bar having a first tab portion, a second tab portion, and a first central body; the first central body of the first bus bar being disposed between the first and second tab portions of the first bus bar; and

the first central body of the first bus bar being disposed within the first substantially rectangular ring-shaped peripheral wall, the first tab portion of the first bus bar extending outwardly from the first substantially rectangular ring-shaped peripheral wall in a first direction, and the second tab portion of the first bus bar extending outwardly from the first substantially rectangular ring-shaped peripheral wall in a second direction perpendicular to the first direction, the first tab portion of the first bus bar being electrically coupled to a first electrical terminal of the first battery cell;

a second bus bar having a first tab portion, a second tab portion, and a first central body; the first central body of the second bus bar being disposed between the first and second tab portions of the second bus bar; and

the first central body of the second bus bar being disposed within the second substantially rectangular ring-shaped peripheral wall, the first tab portion of the second bus bar extending outwardly from the second substantially rectangular ring-shaped peripheral wall in the first direction, and the second tab portion of the second bus bar extending outwardly from the second substantially rectangular ring-shaped peripheral wall in a third direction opposite of the second direction, the first tab portion of the second bus bar being electrically coupled to a second electrical terminal of the second battery cell.

6. The battery assembly of claim **3**, further comprising:

a third battery frame assembly having a third plastic frame member and a third thermally conductive plate;

the third plastic frame member having a third substantially rectangular ring-shaped peripheral wall and a plurality of cross-members; the third substantially rectangular ring-shaped peripheral wall having first, second, third and fourth wall portions defining a central space, the plurality of cross-members of the third plastic frame member extending between the first and second wall portions of the third substantially rectangular ring-shaped peripheral wall and extending across the central space thereof, the plurality of cross-members of the third plastic frame member defining a plurality of open spaces therebetween in the central space of the third substantially rectangular ring-shaped peripheral wall,

the third substantially rectangular ring-shaped peripheral wall further having a third plurality of channels extending into the first wall portion thereof proximate to the plurality of open spaces defined by the plurality of cross-members of the third plastic frame member, and a fourth plurality of channels extending into the second wall portion thereof proximate to the plurality of open spaces defined by the plurality of cross-members of the third plastic frame member;

the third thermally conductive plate having peripheral edges encapsulated within the third substantially rectangular ring-shaped peripheral wall;

a fourth battery frame assembly having a fourth plastic frame member and a fourth thermally conductive plate, the fourth thermally conductive plate having peripheral edges encapsulated in the fourth plastic frame member; and

third and fourth battery cells disposed between the third battery frame assembly and the fourth battery frame assembly such that the third thermally conductive plate contacts the third battery cell, and the fourth thermally conductive plate contacts the fourth battery cell, the third plastic frame member being coupled between and to the first and fourth plastic frame members.

7. The battery assembly of claim **6**, wherein each channel of the first plurality of channels is disposed adjacent to a respective channel of the third plurality of channels, and each channel of the second plurality of channels is disposed adjacent to a respective channel of the fourth plurality of channels; each respective combination of a channel of the first plurality of channels, a channel of the second plurality of channels, a channel of the third plurality of channels, and a channel of the fourth plurality of channels define a flow path.

8. The battery assembly of claim **2**, wherein the first and second plastic frame members have first and second channels, respectively, that extend into the first and second plastic frame members, respectively, that are disposed proximate to one another such that first and second electrical terminals, respectively, of the first and second battery cells, respectively, extend through an aperture formed by the first and second channels.

9. The battery assembly of claim **1**, wherein the first wall portion and the second wall portion of the first substantially rectangular ring-shaped peripheral wall being substantially parallel to one another; the third wall portion and the fourth wall portion of the first substantially rectangular ring-shaped peripheral wall being substantially parallel to one another and substantially perpendicular to the first and second wall portions.

10. The battery assembly of claim **1**, further comprising:

a first bus bar have a first tab portion, a second tab portion, and a first central body; the first central body being disposed between the first and second tab portions; and

the first central body being disposed within the first and third wall portions, the first tab portion extending outwardly from the first wall portion, and the second tab portion extending outwardly from the first wall portion, the first tab portion being electrically coupled to a first electrical terminal of the first battery cell.

11. The battery assembly of claim **1**, further comprising:

a first current sense member having a first current sense lead, a second current sense lead, and a central body; the central body of the first current sense member being disposed between the first and second current sense leads; and

the central body of the first current sense member being disposed within the first and fourth wall portions, the first current sense lead extending outwardly from the first wall portion, and the second current sense lead extending outwardly from the fourth wall portion.

12. The battery assembly of claim **1**, wherein the first plurality of cross-members of the first plastic frame member being substantially parallel to one another and substantially perpendicular to the first and second wall portions of the first substantially rectangular ring-shaped peripheral wall.

13. A battery assembly, comprising:

a first battery frame assembly having a first plastic frame member and a first thermally conductive plate;

the first plastic frame member having a first substantially rectangular ring-shaped peripheral wall; the first substantially rectangular ring-shaped peripheral wall having first, second, third and fourth wall portions defining a first central space;

the first thermally conductive plate having first, second, third and fourth peripheral edges being disposed and encapsulated within the first, second, third and fourth wall portions, respectively, of the first substantially rectangular ring-shaped peripheral wall, the first thermally conductive plate having first and second sides, the first thermally conductive plate further having an exposed portion on the first side thereof disposed in the first central space of the first substantially rectangular ring-shaped peripheral wall configured to contact air flowing past the first side of the first thermally conductive plate to extract heat energy from the first thermally conductive plate;

a first battery cell being disposed on and directly contacting the second side of the first thermally conductive plate;

a second battery cell being disposed on and directly contacting the first battery cell; and

a second battery frame assembly being coupled to the first battery frame assembly such that the first and second battery cells are disposed between the first and second battery frame assemblies; the second battery frame assembly having a second plastic frame member and a second thermally conductive plate;

the second plastic frame member having a second substantially rectangular ring-shaped peripheral wall; the second substantially rectangular ring-shaped peripheral wall having first, second, third and fourth wall portions defining a second central space;

the second thermally conductive plate having first, second, third and fourth peripheral edges being disposed and encapsulated within the first, second, third and fourth wall portions, respectively, of the second substantially rectangular ring-shaped peripheral wall, the second thermally conductive plate having first and second sides, the first side of the second thermally conductive plate being disposed on and directly contacting the second battery cell such that the first and second battery cells are disposed directly between the first and second thermally conductive plates.

14. The battery assembly of claim **13**, wherein:

the first substantially rectangular ring-shaped peripheral wall having at least a first cross-member extending between and coupled to the first and second wall portions of the first substantially rectangular ring-shaped peripheral wall and extending across the first central space; the first cross-member being disposed on and directly contacting the first thermally conductive plate;

the first cross-member defining a first open space between the first cross-member and the first wall portion of the first substantially rectangular ring-shaped peripheral wall in the first central space;

the first cross-member further defining a second open space between the first cross-member and the second wall portion of the first substantially rectangular ring-shaped peripheral wall in the first central space;

the first wall portion of the first substantially rectangular ring-shaped peripheral wall having first and second channels extending therein that fluidly communicate with the first and second open spaces, respectively,

the second wall portion of the first substantially rectangular ring-shaped peripheral wall having third and fourth channels extending therein that fluidly communicate with the second open space; and

the first thermally conductive plate having a first exposed portion disposed in the first open space configured to contact air passing through the first and third channels; and

the first thermally conductive plate further having a second exposed portion disposed in the second open space configured to contact air passing through the second and fourth channels to extract heat energy from the first thermally conductive plate.

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